

CHAPTER VI

**ABUNDANCE OF THE JUVENILES AND ADULTS
AND
REPRODUCTIVE BIOLOGY
OF
Stolephorus baganensis AND *Thryssa kammalensis***

SUMMARY

A study of the juvenile and adult populations of *S. baganensis* in the lower estuary of the Sungai Selangor showed that this species was always found in the study area. However, sex ratios and abundance of individuals at different stages of gonadal maturation suggest that *S. baganensis* resides not only in Sungai Selangor lower estuary, but also in adjacent waters. There are two periods of recruitment of juveniles into the adult stock: a main one from June to September and a secondary one around January-February. The relatively low abundance of ripe females, sampled around noon in this study, suggests spawning at night, as well as a strong segregation of mature females from the rest of the cohort. Females are serial spawners, spawning all year round with two peaks of activity in April and December. The mean density and biomass of juvenile and adult *S. baganensis* (from January 1997 to April 1998) are 120 individuals/ha and 300g/ha, respectively.

T. kammalensis, on the other hand, are temporary residents of the estuary, using it as a spawning as well as nursery ground. Juveniles composed most of the catches from December to March, but after this period their number declined when they leave the estuary for more offshore waters to mature. Females of this species are also serial spawners, but with a long spawning period of about 10 months, with peaks of spawning activity occurring every three months. Sex ratio was characterized by a relatively low number of mature males, suggesting that they do not remain in the estuary with the females but rather make brief incursions into the spawning area to fertilise the spawned eggs. Mean biomass of *T. kammalensis* population is about 250g/ha between January 1997 to April 1998, with a mean density of 73 individuals/ha.

INTRODUCTION

A good number of past studies on clupeids have concluded that many species of anchovies are serial spawners (Tiews *et al.*, 1975; Wright, 1990; Wang & Tzeng, 1999). This phenomenon has contributed to and enhanced their chances of maintaining a relatively stable adult stock despite innumerable hostile environmental factors and a relatively shorter reproductive life-span compared to single spawners (Alheit, 1989; Armstrong & Shelton, 1990). In one species, *Stolephorus heterolobus*, commonly found in the Southern Java Sea, it was observed that females spawn asynchronously to allow daily shedding of eggs, thus enhancing chances of recruitment (Wright, 1990).

The number of spawning and the time interval between batches of eggs vary at the species as well as individual level. Short-lived *Encrasicholina* species in the Solomon Islands and *Stolephorus heterolobus* in South Java Sea spawn every two to eight days and every two to fourteen days respectively, during their entire reproductive life-span (Wright, 1990; Milton *et al.*, 1995); The sardine, *Amblygaster sirm*, herring, *Herklotsichthys quadrimaculatus* and sprat, *Spratelloides delicatulus* have a spawning frequency of three to five days (Milton *et al.*, 1994a); *Stolephorus* species in Indian waters shed three batches of eggs in quick succession, then rest for two to four months before going through another set of multiple spawnings (Luther, 1990). The time interval between spawnings, in many cases, is believed to be correlated to food resources and the energy costs of repeated gonadal maturation (Wright, 1990; Milton *et al.*, 1994b).

More generally, the relationship between food availability and reproduction has been demonstrated by many studies. For instance, fecundity of *Encrasicholina* species was positively correlated with zooplankton density (Milton *et al.*, 1995); the high spawning frequency of *Stolephorus heterolobus* was found to be dependent on prevailing food availability (Wright, 1990). A positive correlation was found between the hepatosomatic index and the spawning time of the sprat *Spratelloides delicatulus* and the herring *Herklotsichthys quadrimaculatus*, thus suggesting an involvement of the energy stored in the liver during reproduction (Milton *et al.*, 1995). Fat in the gut mesenteries of the herring *Clupea harengus* is utilized during gonad maturation (Rajasilta, 1992).

In a similar study, Ré (1987) observed changes in partitioning of energy between growth and reproduction during the spawning season of *Engraulis encrasicolus* in Portugal. According to Schaefer (1996), female *Thunnus albacores* in the Eastern Pacific Ocean used up an average of 2.5 times more energy in reproduction than in somatic growth, while this same ratio was 0.75 in males. Sexual differences have also been observed in the herring, with males presenting a higher condition factor at the beginning of the spawning season than at the end, while it remained constant in females throughout the season (Rajasilta, 1992).

Thus, although the role and importance of food in spawning and in the condition of a fish cannot be denied, the way it is mediated is less clear nor is it specific to any given species or gender. Rajasilta (1992) also pointed out that a genetic control at the individual level could prevail.

The environmental factors affecting fecundity or triggering spawnings have yet to be properly defined. Results reported in related literature show a high variability in the response of fishes to environmental changes between and within species. Temperature, for example, is seen as an important factor affecting fecundity in various ways, one being through an enhancement of the growth rate, which has been shown to work concomitantly with temperature (Alheit, 1989; Palomera, 1992). Spawning in Caribbean reef fishes starts when the sea surface temperature falls to about 28°C (Munro *et al.*, 1973), while the mean spawning season of *S. purpureus* in Hawaii coincides with the peak annual sea temperature cycle (Tester, 1955 cited by Dalzell, 1987). Moreover, several authors have reported a positive relationship between the size of the females and spawning activity. For instance, Alheit (1989) reported that a relatively big female northern anchovy in its fourth spawning year can lay ten times more eggs than during its first year.

Light has been found to be another major environmental parameter affecting reproduction. Spawning occurs in early night in most of the clupeids (Wright, 1992). Therefore, cloud cover and moon phases are implicating factors for the spawning periodicity of fishes. For example, low cloud cover and full moon phase were positively correlated with the spawning activity of tuna in the Solomon Islands, and accounted for about 26% of the variation in spawning periodicity (Milton & Blaber, 1991). The spawning peaks of the tropical clupeid *Herklotsichthys castelnaui*, on the other hand, were associated with the first and third quarter moon phase (Thorrold, 1988). Furthermore, photoperiod and decrease of light levels at late afternoon have been proposed as possible cues detected by the females to release their eggs (Clarke, 1989; Wright, 1990).

Salinity is another environmental factor often associated with researches of similar nature. Anchovies are, in general, believed to be tolerant of a wide range of salinity. Depending on the species, adults and eggs have been found at salinity levels varying between 5‰ and 41‰ (Ré, 1987). In one study, Palomera (1992) correlated a plume of freshwater with the largest spawning activity and presence of *Engraulis encrasicolus* eggs in the northwestern Mediterranean, suggesting a preference of this species for relatively low salinity water. *Stolephorus buccaneeri* and *S. insularis* on the other hand, are found in the highly saline waters of the Tanshui River in Taiwan (Tzeng & Wang, 1992).

A change in the direction of the prevailing winds, often associated with inter-monsoon seasons, has also been linked to spawning peaks (Dalzell, 1987).

In 1996, 420,218 mt of anchovies were harvested from the South China Sea region, thus constituting one of the major marine species of the region (Fisheries Statistical Bulletin 1996, SEAFDEC, <http://www.seafdec.org/td/pub012.htm>). However, despite the economic importance of anchovies in Southeast Asia for direct human consumption as well as for the fish meal industry, no major studies have been carried out in Malaysia to clarify their reproductive biology. Although anchovy stocks are well known to be prolific in Malaysia, they are just as vulnerable as other fish species when it comes to over-fishing. The collapse of the anchoveta fishery of Peru in the early 70s provides strong evidence that an unmanaged fishery can quickly deteriorate into a biological as well as an economic disaster. Concomitantly, as the literature review suggests, an understanding of the fish's ecology and environment in relation to its reproductive requirements, is essential to its overall management. Therefore, the present study has the following main objectives:

- 1) to estimate the size of the standing stocks of juvenile and adult anchovies in the lower estuary, and
- 2) to elucidate the reproductive biology of *S. baganensis* and *T. kammalensis* in the lower estuary.

To achieve the first objective, standing stocks of both species will be estimated based on the swept-area method as carried out by regular trawl surveys. The second objective will be achieved by studying gonadal maturation, gonado-somatic index, spawning activity (including sex ratio, size at first maturity, and spawning season), length-weight relationships, and condition factor.

MATERIALS AND METHODS

1. Field trips

Monthly field trips were organized from January 1997 to April 1998, on the 20th day (± 2 days) of each month, in order to sample adult and juvenile anchovies. Effort was made to sample at a regular date in order to also fulfil the requirements of the Electronic Length Frequency Analysis (ELEFAN) for the population dynamic study (see Chapter VII). As priority was given to sampling at a fixed date, tidal conditions were not always identical, although attempts were made to sample as closely as possible to the neap tide. Since gonadal maturation of females changes fast within 24 hours before spawning (Hunter *et al.*, 1986), samplings were conducted about the same time in order to allow a proper comparison of the monthly catch. In this present study, the collection time was set around noon.

Four stations in the vicinity of the ichthyoplankton survey stations were defined within the lower estuary and sampled once each month. Each station covered a surface area averaging 1.8 km² and was set by 3 km apart (Fig. 6.1). Stations 2 and 4 were the shallowest, averaging 4 m; Station 1 was around 6 m in depth and Station 3 was the deepest, at 10 m.

Samplings were conducted using an otter-trawl. The net had a head-rope length of 49.4 m; the wing to belly mesh sizes measured 23.0 cm, 12.4 cm, 5.6 cm and 4.0 cm, while the codend was 2.5 cm. Within each defined station, the trawl net was towed for 17 minutes at a ground speed of approximately 1.5 m/s. After retrieval of the net, all

anchovies were picked and kept in an ice box. If the trawl catch was too big, it was divided into two or four equal portions. One portion was then taken and sorted completely for anchovies. If sub-sampling occurred, the sample abundance was accordingly multiplied by two or four in order to estimate the actual anchovy catch.

A few specimens from the catch were measured and weighed on the boat, and then slit open at the belly. The maturation stage of the fresh gonads was visually assessed based on the colour and relative volume of the ovary or length of testis to the abdominal cavity. Ovaries and testes were cautiously dissected out and immediately placed in a 10% formalin solution for histological studies.

2. Laboratory procedures

Once back in the laboratory, all specimens were immediately kept at - 20°C in the freezer until later examination. The body weight of each specimen was taken to the nearest 0.1 g and the total length was measured to the nearest millimeter. Upon completion of measurements, their bellies were slit opened using a pair of scissors. The fish was sexed and the stage of gonad maturation was assessed visually. If necessary, the ovaries were checked microscopically to determine the ova sizes. All individuals had their total gonad weight taken to the nearest 0.001 g, and for some specimens, left and right ovaries were weighed separately.

Three sub-fractions of the ovary were taken randomly from 63 and 74 individuals of *S. baganensis* and *T. kammalensis*, respectively, placed in a small dish, and

ova were cautiously separated from the tissues and measured using an ocular micrometer fitted to a compound microscope. In the case of oval-shaped ova, their

length and width were measured and the average taken. Subsequently, the ova sizes from these three portions were statistically compared to check for homogeneity of their size distributions using analysis of variance (ANOVA) and the Newman-Keuls test.

The gonads collected and fixed in formalin during the field trip were brought to the histological laboratory (Institute of Biological Sciences, Universiti Malaya) for histological preparation. The gonads were gradually dehydrated through 70%, 95%, and then absolute alcohol. They were cleared in toluene before being embedded in paraffin wax. Embedded tissues were cut around the mid-region part into 8 μm -sections using a microtome and mounted onto microscope slides. The sections were then deparaffinated by passing them through xylene and then hydrated through a decreasing graded series of alcohol solutions until distilled water. They were then stained in haematoxylin and eosin, dehydrated through an increasing alcohol series, cleared in xylene and finally mounted in Canadian Balsam. No sections were taken on the most anterior and posterior parts of the ovary, as ANOVA showed that the ova were homogeneously distributed (see previous paragraph). For *T. kammalensis*, both left and right ovaries were studied histologically, as a big difference in size between the two gonads was observed.

3. Data analysis

3.1. Fish density and biomass

The monthly density and biomass of *S. baganensis* and *T. kammalensis* were calculated for their populations in the estuary, according to sex and gonad maturation stage. Density was calculated using the swept area method (per Sparre & Venama, 1989), based on the following equation:

$$D = \frac{\{[(n \times 10,000)/A] \times f\}}{1/2}$$

where,

“D” is the density in number of fish per hectare (no./ha); “n” is the number of fish caught; “f” is the sub-sampling factor; “A” is the trawled-over area; and “1/2” is the retention factor (Pauly, 1983). “A” was estimated from the following relation:

$$A = S \times T \times (L/2)$$

where,

“S” is the boat ground speed (in meter/second); “T” is the trawling duration (in seconds); and “L” is the head rope length (in meter).

The head rope length (L) was divided by two to estimate the width of the tow path swept by the trawl (per Sparre & Venema, 1989). Blaber *et al.* (1990) recommended a retention factor of ‘1/3’ instead of ‘1/2’ in the case of fish species of less than 225 mm length. The choice of ‘1/2’ was taken since the sampled area was shallow and its use in the calculations of density and biomass made these estimates comparable to other studies carried out in the Klang Strait (e.g. Chong *et al.*, 1990; Zgozi, 2000).

The estimated density data were transformed $\log(x+1)$ to homogenise the variance and normalise the distribution, as required before using parametric tests (Sokal & Rohlf, 1998). Upon which, monthly data were statistically compared using ANOVA and Newman-Keuls test (Statistica V. 5 software).

Monthly biomass of anchovy in the estuary was calculated using the same procedure for each species according to sex. Since fish with ripe gonads were rare, they were grouped together with the mature individuals (stage F3 or M3) for convenience.

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“D” is the density in number of fish per hectare (no./ha); “n” is the number of fish caught; “f” is the sub-sampling factor; “A” is the trawled-over area; and “1/2” is the retention factor (Pauly, 1983). “A” was estimated from the following relation:

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3.2. Weight-length relationship, condition factor, and gonadosomatic index (GSI)

The analysis of length-weight data is commonly practiced so as to convert one parameter into the other and to detect any variation in the relationship between sexes or between the gonadic maturation stages (Le Cren, 1951). The length-weight relationship is derived from the following power function:

$$W = aL^n$$

where,

"W" is the body weight (in gram), "L" is the body length (in centimeter); "a" is a constant; and "n" an exponent, with a value usually between 2.5 and 4.0.

By definition, an "ideal" fish has "n" equal to 3 throughout its life span (Le Cren, 1951). This indicates that the general body shape is maintained throughout the growth period (isometric growth); any deviation from "3" indicates allometric growth, or change in the body shape. On a double logarithmic (log 10) scale, this relationship is represented by a straight line corresponding to the equation:

$$\log W = \log a + n \log L$$

The condition factor K, also known as ponderal index, gives an indication of the development of the fish. It can be computed by comparing the actual weight of the fish with its theoretical ideal weight (i.e. assuming that $n=3$), which can be expressed as follows:

$$K = W / aL^3$$

However, as not all fishes are "ideal", the relative condition factor, K_n , has been introduced and is commonly used to measure the deviation between the weight of the fish and the expected weight of the fish, \bar{W} , which is obtained from the length-weight

regression (see, Ntiba & Jaccarini, 1990). In this study, the K_n value was used and calculated using the following formula:

$$K_n = W / \bar{W}$$

The gonadosomatic index (GSI) expresses the gonad weight as a percentage of the somatic body weight based on the following formula:

$$GSI = [\text{gonad weight} / (\text{fish weight} - \text{gonad weight})] * 100$$

Fluctuations over time of GSI give an approximate indication of the spawning cycles (Jons & Miranda, 1997). GSI for all specimens (except indeterminate juveniles) were calculated.

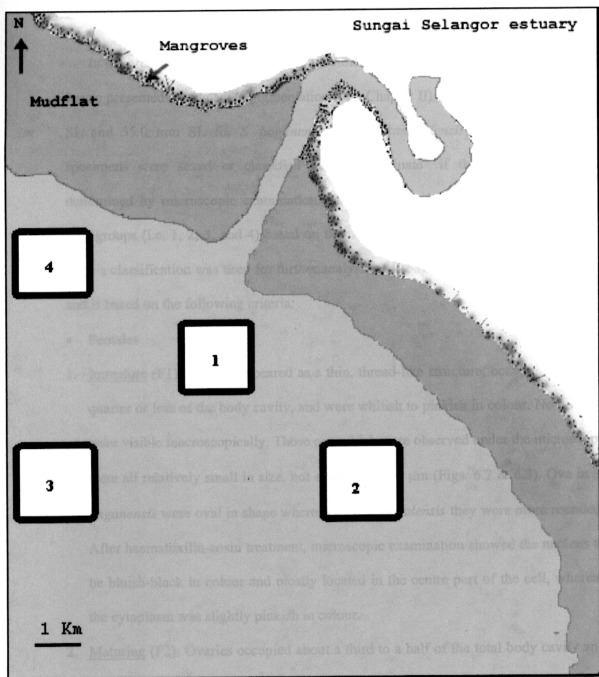


Fig. 6.1. Sampling stations for the survey of adult and juvenile anchovies in the Sungai Selangor lower estuary.

RESULTS

1. Gonad maturation stages

In the present study the onset of the juvenile period was defined as the size at which larvae presented an adult-like pigmentation (see, Chapter II). These sizes were 35.0 mm SL and 55.0 mm SL for *S. baganensis* and *T. kammalensis*, respectively. Bigger specimens were sexed or classified as “indeterminate” if the sex could not be determined by microscopic examination. Thus, males and females were divided into four groups (i.e. 1, 2, 3, and 4) based on the morphology and histology of the gonads. Such a classification was used for further analysis of *S. baganensis* and *T. kammalensis*, and is based on the following criteria:

- Females

1. Immature (F1): Gonads appeared as a thin, thread-like structure, occupying about a quarter or less of the body cavity, and were whitish to pinkish in colour. No oocytes were visible macroscopically. Those ova which were observed under the microscope were all relatively small in size, not exceeding 250 μm (Figs. 6.2 & 6.3). Ova in *S. baganensis* were oval in shape whereas in *T. kammalensis* they were more rounded. After haematoxylin-eosin treatment, microscopic examination showed the nucleus to be bluish-black in colour and mostly located in the centre part of the cell, whereas the cytoplasm was slightly pinkish in colour.
2. Maturing (F2): Ovaries occupied about a third to a half of the total body cavity and were pinkish to orange in colour. Ova of different sizes were visible with the naked eyes, giving the ovary a granular appearance. Microscopic observation of ova revealed various sizes. The smaller ones, commonly present in the “immature

stage", were still abundant, but bigger and more translucent ones were also observed (i.e. up to 625 μm , see Figs. 6.2 & 6.3). The bigger ones progressively lost their regular oval shape and became more elliptical in *S. baganensis*, while the shape remained round in *T. kammalensis*. These bigger ova revealed the presence of yolk globules stained dark blue in colour. These yolk globules were few in number and located at the periphery of the cell in the smaller ova, but more numerous and moving towards the middle in bigger ova.

3. Mature (F3): Ovaries occupied almost the whole body cavity and were more reddish in colour with more pronounced granular appearance. Big translucent ova were easily distinguishable and separable from the other ova and surrounding tissues. Under the microscope, all types of oocytes described above were found in the same ovary. After staining, the bigger ova (up to 875 μm and 1,000 μm in *S. baganensis* and *T. kammalensis*, respectively; see Figs. 6.2 & 6.3) appeared as a "big mass", dark in colour, with a cytoplasm almost totally covered with yolk globules and a relatively thick zona radiata.
4. Spent (F4): Ovaries were smaller and thinner than in the mature stage, occupying about half of the body cavity, and were dark red in colour. Microscopic examination showed a highly vascularised ovary and, as expected, big translucent ova were not present anymore. No histological study was conducted on these specimens as they were rare and not found in time during field sampling and sorting to conduct a proper preservation of the gonads.

- Males

1. Immature (M1): Testes were flat, thread-like, elongated and white in colour, occupying less than half of the body cavity length.

2. Maturing (M2): Testes were elongated from $\frac{1}{2}$ to $\frac{3}{4}$ of the body cavity length. They were thicker and cream in colour with wavy edges.
3. Mature (M3): Testes filled most or entire body cavity and were white in colour. Milt exuded with a slight or no pressure in more ripe specimens.
4. Spent (M4): Testes were elongated, flatter, and shrunken in appearance, and were pinkish in colour.

Hence, with this classification, juveniles would include “immature” and “maturing” males or females and individuals of “indeterminate” sex. The adult stage includes “mature” and “spent” male or female fishes. The onset of adulthood, or size at first maturity, was estimated by the fish length corresponding to the mark where 50% of observed individuals were “mature” males (M3 & M4) or females (F3 & F4). In the case of *S. baganensis*, this size was approximately 6.2 cm and 6.3 cm for females and males, respectively (Figs. 6.4 & 6.5), while for female *T. kammalensis* it was close to 7.9 cm (Fig. 6.6). Size at first maturity could not be defined for male *T. kammalensis* as too few specimens of stage M3 were captured (see, Fig. 6.22.c).

Ova sizes for ovaries of different maturation stages are presented in Figs. 6.2 and 6.3 for *S. baganensis* and *T. kammalensis*, respectively, and are expressed in percentages of occurrence per size-class of 125 μm . Although the left ovary of *T. kammalensis* was always bigger than the right one, microscopic examination did not show any histological differences to suggest any difference in maturity between the left and right ovaries. The weight ratio of the left to right ovary was not consistent and varied between 3:1 and 6:1.

Ova were uniformly distributed in the ovary, with no significant differences ($p>0.05$) between the overall ova size in the anterior, medium, and posterior part of the gonad.

2. *Stolephorus baganensis*

2.1. Stock density and biomass

Descriptive statistics of the density of *S. baganensis* at Sungai Selangor lower estuary over the 16 months of study are given in Fig. 6.7.a, b, and c. No data are presented for October as no sampling was carried out. Results show that the fish were present throughout the year, but with a wide variation in monthly abundance. ANOVA however did not indicate any significant differences among monthly abundances. Figs. 6.8.a and b show the percentage composition of the fish population by adult and juvenile (Fig. 6.8.a) and by female, male, and indeterminate juvenile (Fig. 6.8.b). From the graph in Fig. 6.8.b. it appears that males were most of the time outnumbering females. The month of May 1997 showed the minimum difference between the abundance of male and female *S. baganensis* over the whole studied period, with females representing 42% of the population and males representing 45% of the population. The maximum difference was observed in December 1997, when males and females comprised 64% and 27% of the population, respectively (thus corresponding to a maximum difference of 31%). Only in February and November of 1997 and in March 1998 females were more numerous. "Indeterminate" individuals were relatively abundant from June to September of 1997, and in February and March 1998, representing from 30% to 65% of the total monthly anchovy catch (Fig. 6.8.b).

In all months except in February 1997 juveniles were more abundant than the adults (Fig. 6.8.a), although the latter were always found in the estuary (Fig. 6.7.b). Juvenile higher means of abundance were recorded from January to April of 1997 and in January 1998, while they were very rare from February to April of 1997 (Fig. 6.7.b). The monthly composition of *S. baganensis* in terms of percentage of abundance of juveniles and adults show that the relative number of adults, or the spawning stock, was maximum in February 1997, then declined steadily until August 1997. From September 1997 to January 1998 the percentage of adults increased slightly, but never exceeded 20% of the population (Fig. 6.8.a).

Monthly biomass of the *S. baganensis* population in the estuary indicated a maximum mean value of approximately 700 g/ha recorded in January 1998 (Fig. 6.9.a). The relative biomass of juveniles and adults showed a similar monthly pattern as the relative density pattern of both groups (Figs. 6.8.a. & 6.9.b). However, from March to July of 1997, although adults were relatively less abundant than juveniles, they contributed to a higher percentage of the monthly biomass. In other months, percentage density and percentage biomass of juveniles and adults were almost similar (Figs. 6.8.a & 6.9.b).

Figs. 6.10, 6.11, and 6.12 show the descriptive statistics of female, male, and indeterminate *S. baganensis*, respectively. The ratios F1:M1 and F2:M2 varied widely between months, with the biggest difference recorded in September 1997 (22.9:1.0) and January 1998 (1.0:19.5), respectively (Figs. 6.10.a & b and 6.11. a & b). Over the 15 months (October not sampled) F1 individuals were, on average, 4.4 times more abundant than M1 individuals (Figs. 6.10.a & 6.11.a), while M2 individuals were three times more abundant than F2 individuals (Figs. 6.10.b & 6.11.b). Maturing females (F2)

were half as abundant as immature females (F1) over the whole study period, whereas maturing males (M2) were about seven times more abundant than immature males (M1). Overall, monthly density of F1 individuals (Fig. 6.10.a) followed that of the indeterminate juveniles (Fig. 6.12). Monthly density of M1 males (Fig. 6.11.a), although much lower compared to indeterminate juvenile (Fig. 6.12) and female (Fig. 6.11.a) densities, showed relatively higher values for the months of January to April of 1997 and December 1997 to February 1998. F2 and M2 individuals were present at all months, with no significant difference ($p>0.05$) between their monthly densities. The trend in monthly abundance as observed in the indeterminate and stage 1 juveniles of both genders was not observed in the maturing groups (F2 and M2).

Mature and spent individuals were present in the same range of densities for males (Figs. 6.11.c & d) and females (Figs. 6.10.c & d). However, interestingly, while M3 males were found in all months, except in March 1998, F3 females were found from January to April of 1997 and in November 1997. Mature males (M3) were relatively more abundant in the lower estuary from February to July of 1997 than for the rest of the study period. Spent males (M4) were found in much lower densities compared to mature males (M3) but followed a similar pattern of abundance. However, no spent males (M4) were captured in February 1997, and very few in April 1997, in contrast to M3 individuals. Spent females (F4) were also very few compared to all other stages, but they were more frequently captured than F3 individuals. However, for the three months of March, September, and November of 1997, no spent females were observed. The abundance patterns of F4 females and M4 males showed little similarity, except for relatively higher records for the months of May to July of 1997 and January 1998.

2.2. Gonadosomatic index

Gonadosomatic index (GSI) for immature, maturing, mature and spent individuals are presented in Figs. 6.13.a and 6.13.b for females and males, respectively. Results show that the GSI over the study period averaged 0.9, 2.0, 3.5, and 1.0 for immature, maturing, mature, and spent females, respectively, with a maximum record of 5.8 for an adult female in April 1997. Male GSI averaged 0.9, 2.5, 4.5, and 1.0 for immature, maturing, mature, and spent individuals, respectively, with a maximum value of 18.7 for an adult male in January 1998. GSI of immature and maturing individuals of both males and females did not vary much between months ($SD = \pm 0.2$), whereas for mature and spent individuals variations were higher ($SD = \pm 0.8$).

The monthly mean gonadosomatic index (GSI) for female and male *S. baganensis* over the study period are displayed in Figs. 6.14.a and b, respectively. Results show relatively higher GSI values for females from January to April 1997 and in November 1997, compared to the other months, particularly June and December where the GSI were lowest (Fig. 6.14.a). In contrast, this pattern was less obvious for the male population where relatively higher GSI were found from February to May of 1997 (except March) (Fig. 6.14.b). For both male and female populations, standard deviations were high, probably due to the pooling of all gonad maturation stages in the analysis.

2.3. Length-weight relationships and relative condition factor

Figs. 6.15.a and 6.15.b show the log length-log weight relationships for female and male *S. baganensis*, respectively. The linear function illustrating the length and weight

relationship (i.e. $\log W = \log a + n \log L$) was almost identical for males and females, showing no marked sexual differences in the body growth of adult *S. baganensis*. The “n” value equalled to 3.04 and 3.05 for females and males, respectively, thus following the cubic law and the definition of an “ideal fish” as proposed by Le Cren (1951). Hence, the equations of the length-weight relationship for female and male *S. baganensis* are given by $W = 0.013 L^{3.04}$ and $W = 0.012 L^{3.05}$, respectively.

The largest female and male measured were 9.0 cm and 8.1 cm, respectively, whereas the smallest individual of indeterminate sex measured 2.7 cm.

Monthly relative condition factor (Kn) of female, male, and indeterminate juvenile *S. baganensis* and its value for each gonad maturation stage are given in Figs. 6.16 and 6.17, respectively. Results show similar values and monthly variations for both sexes (Figs. 6.16.a & 6.16.b). Mean values ranged between 1.5 and 2.0 in all adults, except for a slightly higher value for the females in March 1998. Kn values were similar for F2, F3, and F4 individuals (Fig. 6.17.a), whereas they increased gradually for males of stages 1 to 3, 4 (Fig. 6.17.b). Kn values of the juvenile population showed higher inter-monthly fluctuations, between 0.6 and 1.3 (Fig. 6.17.c).

3. *Thyssa kammalensis*

3.1. Stock density and biomass

Monthly descriptive statistics of *T. kammalensis* population at Sungai Selangor lower estuary are presented in Figs. 6.18.a, b, and c. Results show that the juveniles and adults of this species were not always found in the sampling area (Fig. 6.18.a). Indeed,

no specimens were captured in February 1997 and January 1998, and very few (mean abundance less than 5.0/ha) in December 1997, February, and April of 1998. Relatively high densities were recorded in January, April, August, and November of 1997. Further analysis of the population showed that juveniles were the main representatives of *T. kammalensis* population although they were absent from Sungai Selangor lower estuary in February 1997 and January 1998 (Fig. 6.18.c). In May 1997, and February and April of 1998 adults composed at least 50% of the catch, with the highest percentage recorded in May 1997 (Fig. 6.19.a). However, it is in April 1997 that the highest mean and median values were recorded (Fig. 6.18.a). No adults were captured in the months of February and December of 1997 and January and March of 1998 (Fig. 6.18.a).

Male and female densities were uneven for the months of relatively low abundance of indeterminate, with females being at least twice more abundant than males, except for the month of November 1997 when males were slightly more abundant (Fig. 6.19.b). For the months of relatively high number of indeterminates, abundance of males and females showed more homogeneity (Fig. 6.19.b).

Total monthly biomass data (Fig. 6.20.a) were not always related to the relative density and biomass of the adults (Figs. 6.19.a & 6.20.b); for instance, the highest monthly density, recorded in November 1997, was mainly attributed to the juvenile population.

As in Figs. 6.18.c and 6.19.a, juvenile *T. kammalensis* were present at all months except in February 1997 and January 1998. Other months showed wide fluctuations in fish densities accompanied by high standard deviations. ANOVA did not show any significant differences ($p > 0.05$) between monthly data. However, as shown in Fig.

6.18.c, a relatively higher fish density was recorded from January to November of 1997, while the following five months showed very little abundance.

Abundances of females (in no./ha) in terms of their ovary development stage are represented in Figs. 6.21.a, b, c, and d. Over the 15 months of field collections, twice as many maturing females (F2) were captured compared to the immature ones (F1), while the number of F2 and F3 individuals were almost identical (141.6/ha and 144.4/ha, respectively). In terms of monthly variations of abundance, these three groups showed a similar trend characterized by a relatively higher number of individuals in January, April to September, and November of 1997. The following five months presented very low abundance values for all groups. Spent females (F4) were captured over five months, namely January, April, May, August, and November of 1997, thus coinciding with the highest mean of abundance recorded for the F3 group. For the remaining nine months, no F4 females were captured. The overall abundance of this group of females was relatively low, never exceeding a mean of 5.8/ha.

Descriptive statistics of the abundance of male *T. kammalensis* (no./ha) in terms of their testis development stages are given in Figs. 6.22.a, b, c, and d. Immature males (M1) were present within the same range of abundance as the immature females (Figs. 6.21.a & 6.22.a). Most of M2 individuals were captured between April to November of 1997, with a relatively high peak of abundance in November. Mature (M3) and spent (M4) males were found in two and three months, respectively. Thus, male M3 were found in May and September, while the spent individuals were present mainly in April, with some in May and July of 1997.

Monthly abundance of indeterminate juveniles is shown in Fig. 6.23. Young *T. kammalensis* were captured every month except in February 1997 and January 1998. Relatively higher abundances were recorded from January to September of 1997 compared to the rest of the study period.

3.2. Gonadosomatic index

Females gonadosomatic index (GSI) during the study period averaged 0.7, 2.0, 4.7, and 1.5 for the immature (F1), maturing (F2), mature (F3), and spent (F4) stages, respectively (Fig. 6.24.a). A maximum GSI of 18.8 for mature female was recorded in August 1997. Except for the immature stage, all other stages demonstrated high standard deviations of the GSI. High GSI values were witnessed in August and September of 1997 for maturing and mature females, respectively. The lowest GSI for F4 females (spent) were recorded concomitantly with the highest GSI for F3 females (mature).

Figs. 6.25.a and 6.25.b show the gonadosomatic index (GSI) for the entire female and male populations, respectively. Peak GSI for females were observed in May and September when mean GSI exceeded 3.0%. Lower GSI were observed in January-February (i.e. close to 1.0) and another in June-July (i.e. close to 2.0). However, in the case of male population very little differences were noticeable among the monthly indices.

Gonadosomatic indices for both M1 and M2 males were relatively low (less than 1.0) with a slight fluctuation over the 16 months of study. The only two indices which

were available for M3 individuals were close to 3.5. GSI for spent males were observed to be similar to the GSI of immature individuals (Fig. 6.24.b).

3.3. Length-weight relationships and relative condition factor.

Figs. 6.26.a and 6.26.b show the log length-log weight relationships for females and males, respectively. The linear equations (i.e. $\log W = \log a + n \log L$) representing the relationship between length and weight were quite similar for both sexes; the "n" values for female and male were 3.21 and 3.36, respectively. Hence, the equations of the length-weight relationship for female and male *T. kammalensis* are given by $W = 0.008 L^{3.21}$ and $W = 0.006 L^{3.36}$, respectively.

The largest female and male specimens measured 8.9 and 9.5 cm, respectively, and the smallest indeterminate specimen was 3.0 cm.

Monthly relative condition factors (Kn) for female, male, and indeterminate sex are shown in Figs. 6.27.a, b, and c while Kn values for each maturation stage are shown in Figs. 6.28.a and b for female and male, respectively. Results indicate a similar monthly pattern of Kn values for both sexes, although fluctuations of mean Kn values were wider for males (i.e. 1.8 to 3.0) than for females (i.e. 2.4 to 3.0). For both sexes, the highest Kn value was recorded in May 1997. The Kn value increased with stage of gonad maturation, for both females and males (Figs. 6.28.a & b). Kn values for juveniles of indeterminate sex (Fig. 6.27.c) were lower, between 0.9 and 1.8, in comparison to that of males and females.

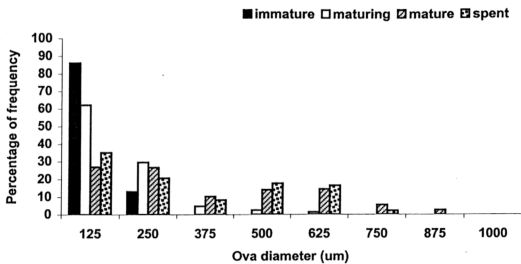


Fig.6.2. Size-frequency distribution of ova in the ovary of *S. baganensis* by maturation stages. Ova diameter at size-intervals of 125 um.

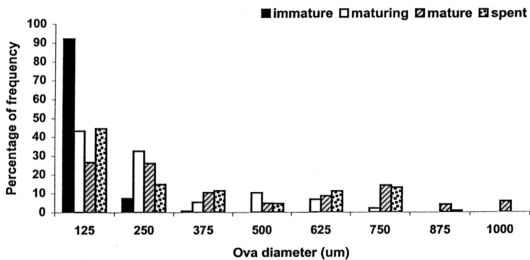


Fig.6.3. Size-frequency distribution of ova in the ovary of *T. kammalensis* by maturation stages. Ova diameter at size-intervals of 125 um.

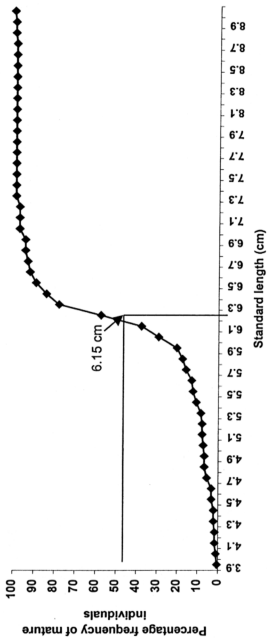


Fig.6.4. Percentage frequency of mature female (F3) *S. baganensis* by standard length.
The length at which 50% of individuals were mature defines the length at first maturity.

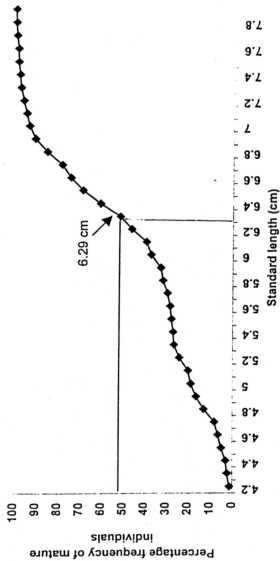


Fig.6.5. Percentage frequency of mature male (M3) *S. baganensis* by standard length.
The length at which 50% of individuals were mature defines the length at first maturity

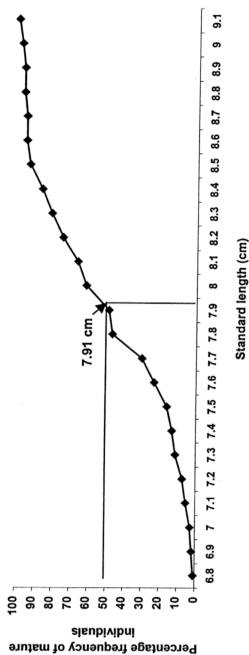


Fig.6.6. Percentage frequency of mature female (F3) *T. kammalensis* by standard length.
The length at which 50% of individuals were mature defines the length at first maturity.

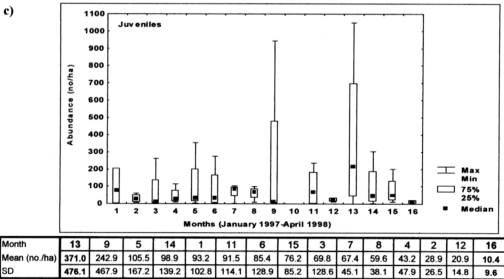
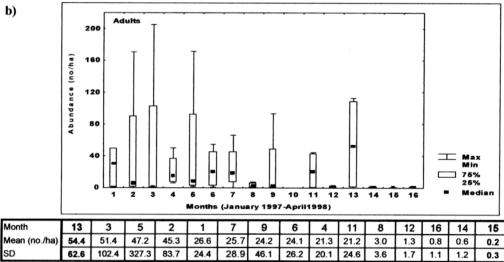
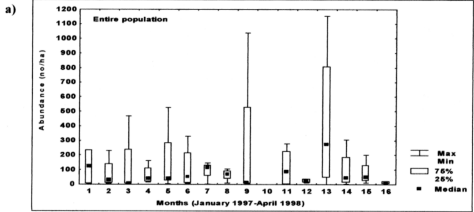


Fig. 6.7. Temporal abundance (no./ha) of the entire population (a), adults (b) and juveniles (c) of *S. baganensis* in Sg. Selangor estuary over the 16 months of study (Jan. 1997 - Apr. 1998). Vertical lines indicate minimum and maximum values; vertical bars indicate first and third quartiles; square dots indicate median; bottom box gives mean abundance (no./ha) and standard deviation (SD) arranged in order of magnitude by month of sampling (no sampling for the month of October).

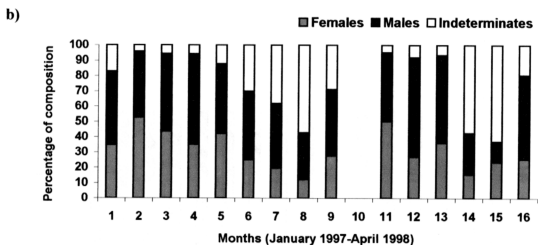
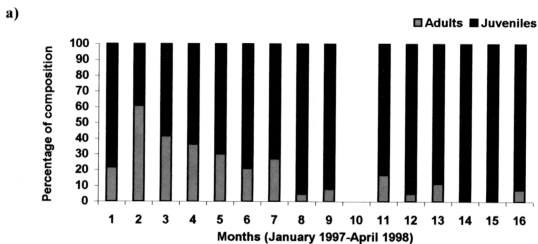
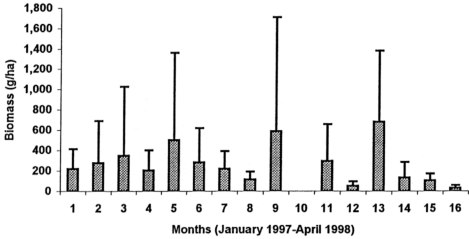


Fig.6.8. Percentage composition (based on fish density) of a) adults and juveniles, and b) females, males, and indeterminate juveniles of the *S. baganensis* population in Sungai Selangor estuary from January 1997 to April 1998.

a)



b)

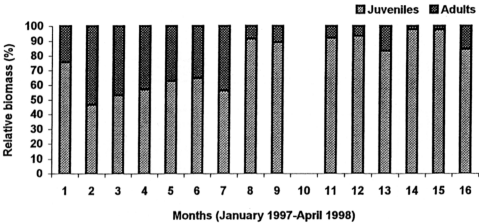


Fig.6.9. a) Monthly mean biomass (g/ha) and standard deviation of *S. baganensis* population at Sg. Selangor estuary over the 16 months of study (January 1997 to April 1998). No data for the month of October (10).

b) Relative biomass (in percentage) of adults and juveniles *S. baganensis* at Sg. Selangor estuary over the 16 months of study (January 1997-April 1998). No data for the month of October (10).

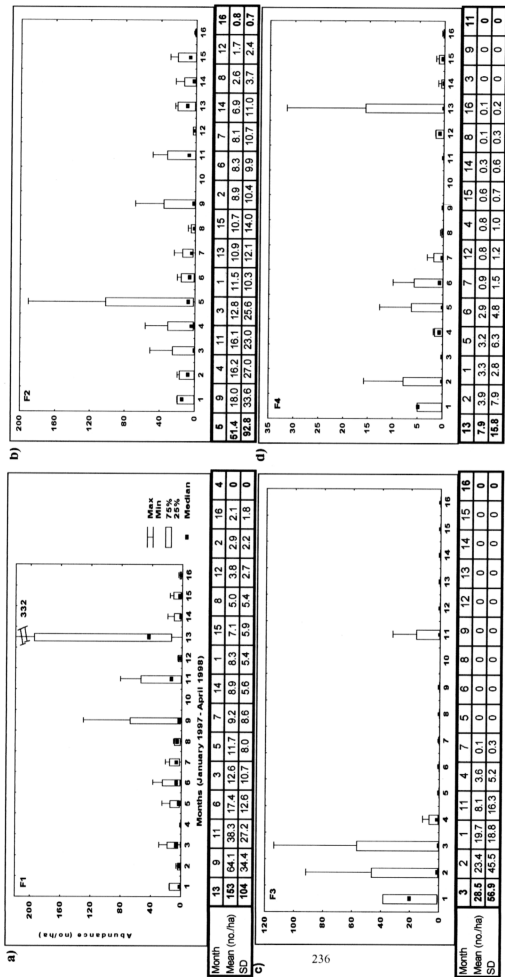


Fig.6.10. Temporal abundance (no./ha) of female (F) *S. baganensis* in Sg. Selangor estuary over the 16 months of study (Jan. 1997 - Apr. 1998) for the a) immature (F1); b) maturing (F2); c) mature (F3); and d) spent stages (F4). Vertical lines indicate minimum and maximum values; vertical bars indicate first and third quartiles; square dots indicate median; bottom box gives mean abundance (no./ha) and standard deviation (SD) arranged in order of magnitude by month of sampling (no sampling for the month of October).

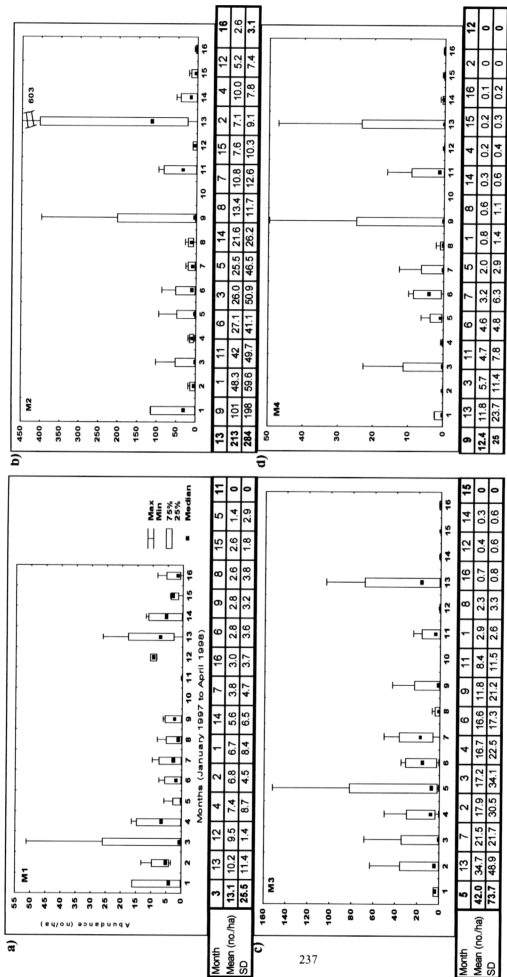


Fig. 6.11. Temporal abundance (no./ha) of male (M) *S. baganensis* in Sg. Selangor estuary over the 16 months of study (Jan. 1997 - Apr. 1998) for the a) immature; (M1); b) maturing (M2); c) mature (M3); and d) spent stages (M4). Vertical lines indicate minimum and maximum values; vertical bars indicate first and third quartiles; square dots indicate median; bottom box gives mean abundance (no./ha) and standard deviation (SD) arranged in order of magnitude by month of sampling (no sampling for the month of October).

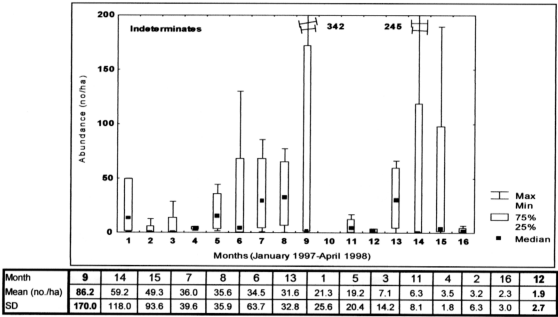


Fig. 6.12. Temporal abundance (no./ha) of indeterminate juvenile *S. baganensis* in Sg. Selangor estuary over the 16 months of study (Jan. 1997 - Apr. 1998). Vertical lines indicate minimum and maximum values; vertical bars indicate first and third quartiles; square dots indicate median; bottom box gives mean abundance (no./ha) and standard deviation (SD) arranged in order of magnitude by month of sampling (no sampling for the month of October).

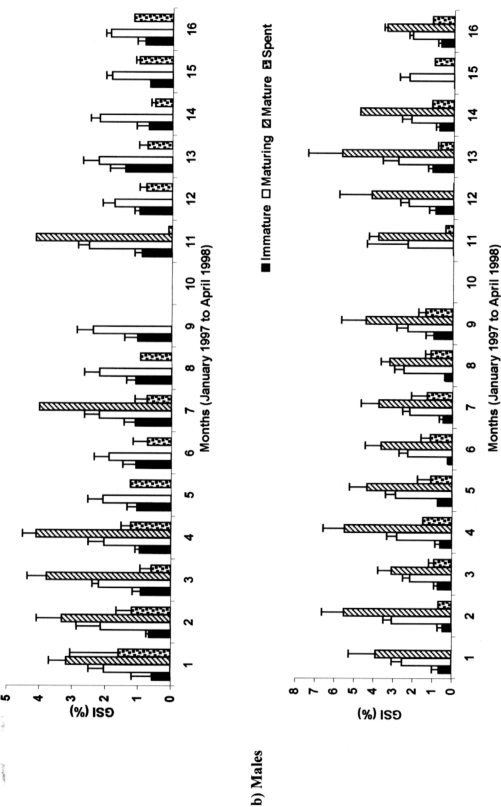
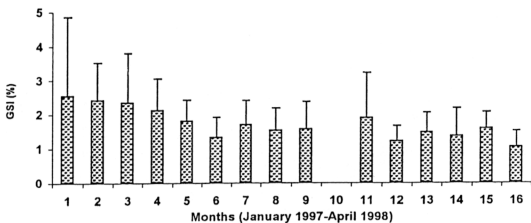


Fig. 6.13. Monthly mean of the gonadosomatic index (GSI) and standard deviation for female (a) and male (b) *S. baganensis* according to the gonad maturation stage. No data for the month of October (10)

a) Females



b) Males

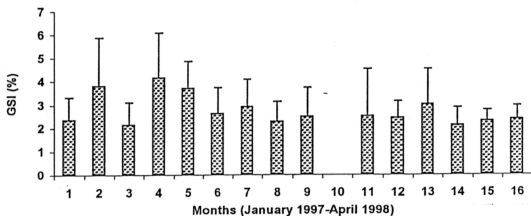
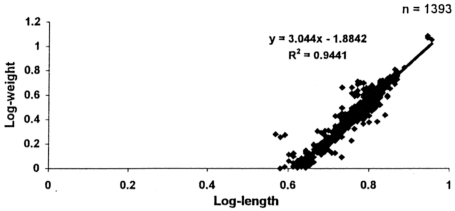


Fig.6.14. Monthly mean of the gonadosomatic index, GSI, (+ standard deviation) for female (a) and male (b) *S. baganensis* over the study period. No data for the month of October.

a) Females



b) Males

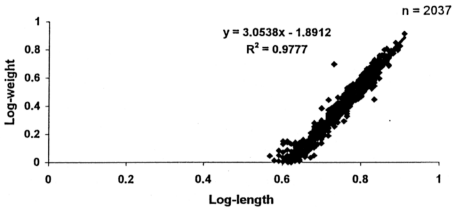


Fig. 6.15. Length-weight relationship on a logarithmic scale, for female (a) and male (b) *S. baganensis* in Sg. Selangor estuary, from January 1997 to April 1998. n = number of individuals.

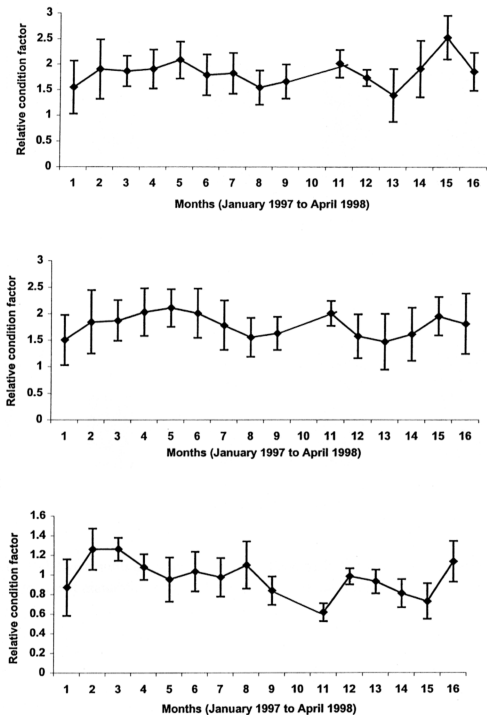
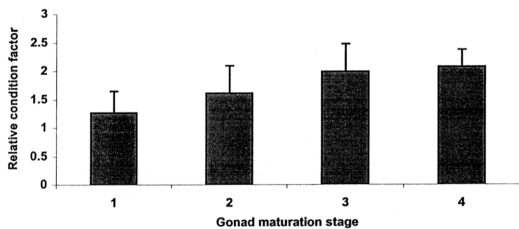
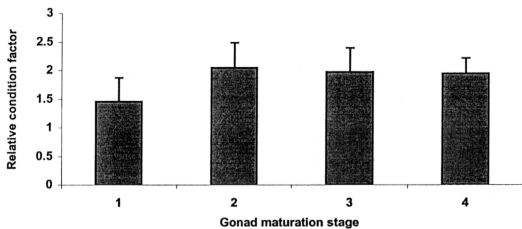


Fig. 6.16. Monthly mean of the relative condition factor (K_n) of females (a), males (b) and indeterminate juveniles (c) of *S. baganensis* in Sg. Selangor estuary from January 1997 to April 1998.



g. 6.17. Relative condition factor of female (a) and male (b) *S. baganensis* according to gonad maturation stages (1= immature; 2= maturing; 3= mature; 4= spent)

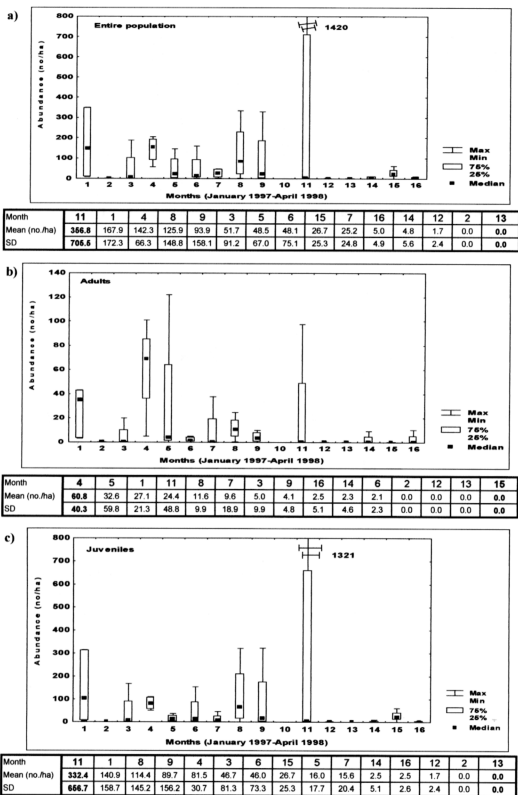


Fig.6.18. Temporal abundance (no./ha) of the entire population (a), adults (b) and juveniles (c) of *T. kammalensis* in Sg. Selangor estuary over the 16 months of study (Jan. 1997 - Apr. 1998). Vertical lines indicate minimum and maximum values; vertical bars indicate first and third quartiles; square dots indicate median; bottom box gives mean abundance (no./ha) and standard deviation (SD) arranged in order of magnitude by month of sampling (no sampling for the month of October).

a)

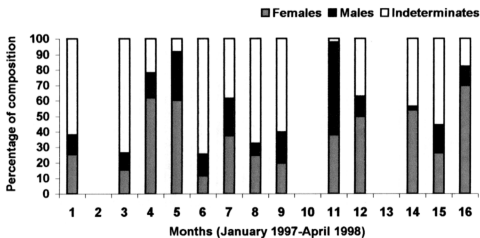
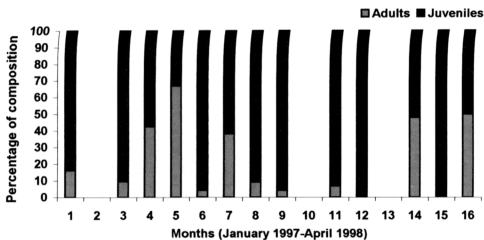


Fig.6.19. Percentage composition (based on their density) of a) adults and juveniles, and b) females, males, and indeterminate juveniles of the *T. kammalensis* population in Sg. Selangor estuary from January 1997 to April 1998.

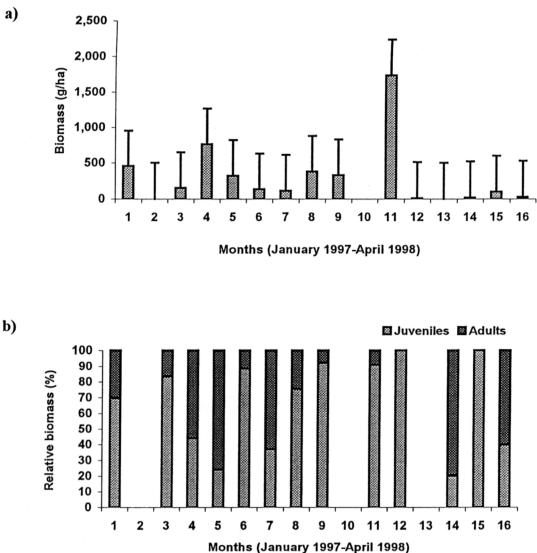


Fig. 6.20. a) Monthly mean biomass (g/ha) and standard deviation of *T. kammalensis* population at Sg. Selangor estuary over the 16 months of study (January 1997-April 1998). No data for the month of October (10).
 b) Relative biomass (in percentage) of adults and juveniles *T. kammalensis* at Sg. Selangor estuary over the 16 months of study (January 1997-April 1998). No data for the month of October (10).

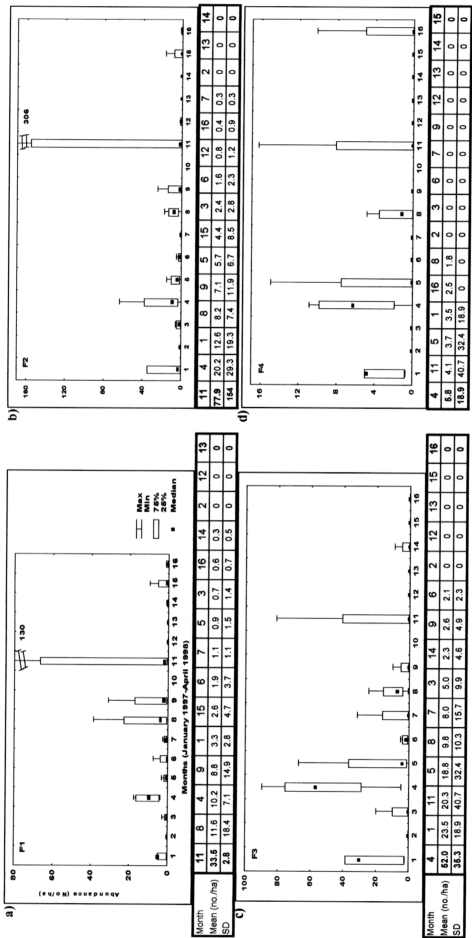


Fig.6.21. Temporal abundance (no./ha) of female (F) *T. kammdensis* in Sg. Selangor estuary over 16 months of study (Jan. 1997-Apr. 1998) for the a) immature (F1); b) maturing (F2); c) mature (F3); and d) spent (F4) stages. Vertical lines indicate minimum and maximum values; vertical bars indicate first and third quartiles; square dots indicate median; bottom box gives mean abundance (no./ha) and standard deviation (SD) arranged in order of magnitude by month of sampling (no data for the month of October).

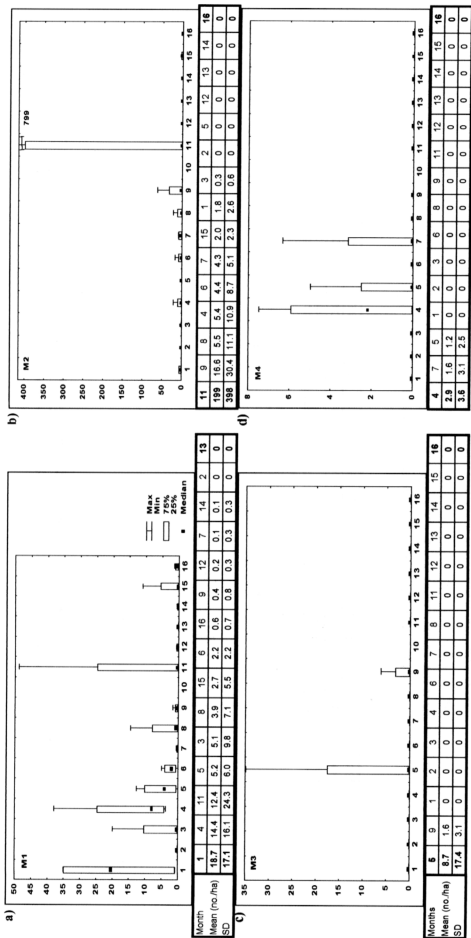


Fig.6.22. Temporal abundance (no./ha) of male (*M. T. kammalensis* in Sg. Selangor estuary over 16 months of study (Jan. 1997–Apr. 1998) for the a) immature (M1); b) maturing (M2); c) mature (M3); and d) spent (M4) stages. Vertical lines indicate minimum and maximum values; vertical bars indicate first and third quartiles; square dots indicate median; bottom box gives mean abundance (no./ha) and standard deviation (SD) arranged in order of magnitude by month of sampling (no data for the month of October).

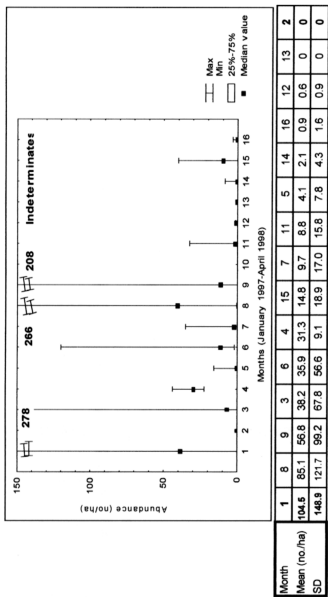
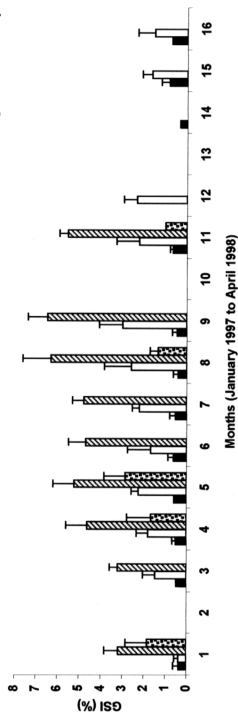


Fig. 6.23. Temporal abundance (no./ha) of juvenile *T. kammalensis* in Sg. Selangor estuary over the 16 months of survey (Jan. 1997-April 1998). Vertical lines indicate minimum and maximum values; vertical box indicate first and third quartiles; square dots indicate median; bottom box gives mean abundance (no./ha) and standard deviation (SD) arranged in order of magnitude by month of sampling (no sampling for the month of October).

■ Immature □ Maturing ▨ Mature ▩ Spent



b) Males

■ Immature □ Maturing ▨ Mature ▩ Spent

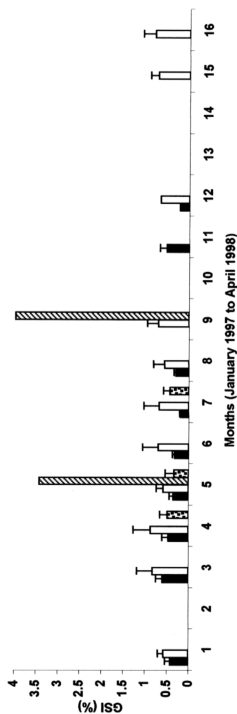
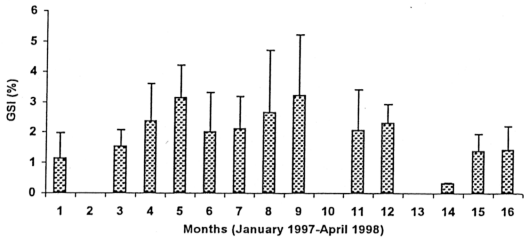
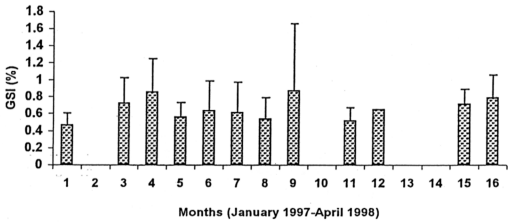


Fig. 6.24. Monthly mean of the gonadosomatic index (GSI) and standard deviation for female (a) and male (b) *T. kammalensis* according to the gonad maturation stage. No data for the month of October (10).

Females

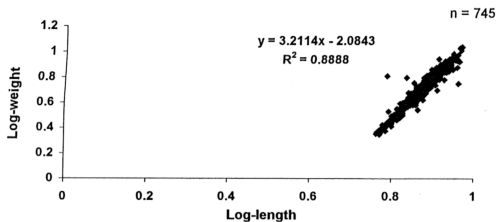


Males



6.25. Monthly mean of the gonadosomatic index, GSI, (+ standard deviation) for female (a) and male (b) *T. kammalensis* over the study period. No data for the month of October.

a)



b)

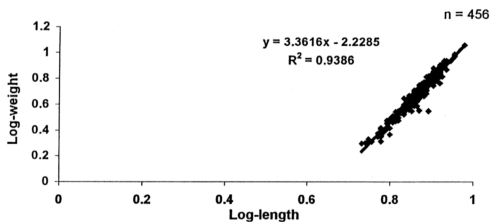
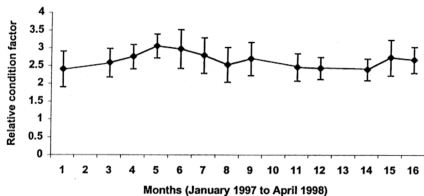


Fig.6.26. Length-weight relationship on a logarithmic scale, for female (a) and male (b) *T. kammalensis* in Sg. Selangor estuary, from January 1997 to April 1998. n = number of individuals.

a)



b)

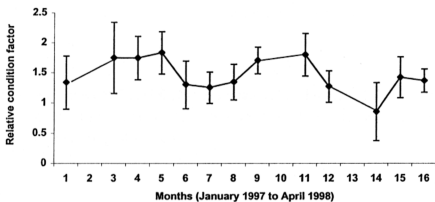
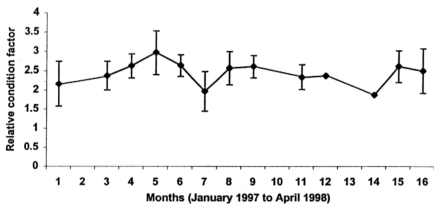
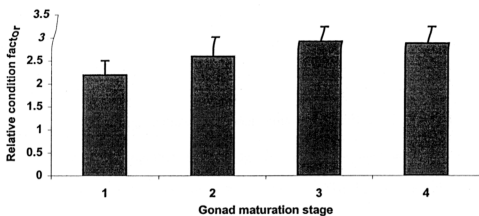


Fig. 6.27. Monthly mean of the relative condition factor (K_n) of females (a), males (b) and indeterminate juveniles (c) of *T. kammalensis* in Sg. Selangor estuary from January 1997 to April 1998.

a)



b)

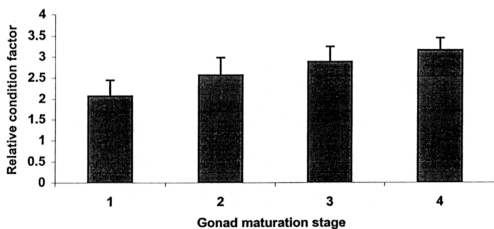


Fig. 6.28. Relative condition factor of female (a) and male (b) *T. kammalensis* according to per gonad maturation stages (1 = immature; 2 = mature; 3 = maturing; 4 = spent)

DISCUSSION

1. Gonad maturation stage

Maturing, mature and spent females of both species have both small and big ova occurring together suggesting that *S. baganensis* and *T. kammalensis* are serial spawners. The homogeneity of the ova distribution regardless of their size, is in agreement with the results of Laroche and Richardson (1980) and Sanz and Uriarte (1989) for *Engraulis mordax* and *E. encrasicolus*, respectively.

The absence of big ova in immature females indicates that these individuals had not spawned before. The rare observation of hydrated ova in both species, a characteristic of gravid or "oozing" females, could be due to the fact that ova of engraulids undergo the hydration stage just a few hours before spawning (Leary *et al.*, 1975; Hunter *et al.*, 1986). Additionally, as spawning has been reported to occur around midnight for several Engraulididae species (e.g. Wright, 1992, for *Encrasicholina heteroloba*), it is likely that both studied species behave the same in which case the sampling time (i.e. noon) was too early in the day to capture females with already hydrated ova.

2. *Stolephorus baganensis*

2.1. Stock density and biomass

The presence of adult and juvenile *S. baganensis*, over the 16 months of survey, (Figs. 6.7.b & c) indicates that this species uses the estuary and adjacent waters as a

living ground or habitat. The estimated mean abundance of 120 individuals/ha in this study is higher than the mean of 84 individuals/ha in the Klang Strait as reported by Zgozi (2000) for the period of October 1996 - October 1997. The relatively high abundance of adult *Stolephorus carpentariae* and *S. devisi* in Australian estuaries was attributed to their planktivorous feeding habits (Blaber, 1980). Hence, estuaries being relatively rich in plankton as compared to offshore waters (Blaber, 1981), are particularly preferred by planktivores such as *Stolephorus* species (Agate *et al.*, 1991). However, Zgozi (2000) who sampled in the whole Klang Strait showed that *S. baganensis* were also relatively abundant at Sg. Buloh estuary and Angsa Bank (Fig. 6.29). The presence of *S. baganensis* at Sg. Buloh estuary and Angsa Bank, two rather shallow areas (see Zgozi, 2000), would suggest that this species does not select particular estuarine or coastal areas to but can accept several types of environments. It also indicates that depth (i.e. less than 5m) could be an important criterion in the selection of habitat by *S. baganensis*.

Since the "indeterminate" juveniles are the youngest individuals to join the maturing and adult stock in the immediate offshore waters, it is of great interest to understand their recruitment pattern for fishery management purposes. The results indicate high monthly variations in the recruitment of these indeterminate juveniles which are not unexpected since these young fish are periodically recruited from the nursery area. Based on the abundance of indeterminate juveniles, two periods of recruitment can be defined: a minor one in January 1997 and a major one from June to September of 1997. The minor one was repeated in February~March 1998 with higher density (Fig. 6.12). The difference in the onset of the first annual recruitment between the two years could be explained by (1) different peak spawning times, as a consequence of yearly environmental changes, and/or (2) differences in the duration of

the larval period, as a consequence of variable environmental conditions for the growth of the young.

Indeterminate juveniles were however present every month (Fig. 6.12), showing that besides the two main recruitment periods mentioned above, recruitment was essentially a continuous process throughout the year. This is supported by the larval studies which show the continuous presence of larvae in the nursery area (see Chapter III, Section 1.1). Similar results were reported for other tropical Engraulididae (Tiews *et al.*, 1975; Luther, 1990), while Milton *et al.* (1996) reported a continuous recruitment of short-lived clupeoids in tropical South-Pacific occurring at a constant monthly rate and representing about one quarter of the catch (Milton *et al.*, 1996).

2.2. Reproductive biology

2.2.1. Sex ratio

By definition, permanent residents of a defined area are those found throughout the year and are present at all maturation stages. Both conditions are satisfied by *S. baganensis*, as shown in Figs. 6.7.a, 6.10, and 6.11, and as discussed above.

Immature and maturing males and females were captured every month, although without any consistency in the monthly sex ratio; this suggests that (1) there could be a sexual segregation among these individuals, or that (2) there is a natural imbalance of the sex ratio of *S. baganensis*.

Sexual segregation in *S. baganensis* is however not apparent because in all catches males and females were always found together although in unequal ratios. The sampling

regime of four trawls in the lower estuary covered a total ground area that ranged between 15-20 ha, which is sufficient to "average" the effects of patchiness and segregation of sexes if any. Hence, it is more likely that natural imbalance in the sex ratio was responsible for the different densities of male and female populations rather than sexual segregation. Additionally, it appears that this unequal number of females and males *S. baganensis* was not consistent each month (Figs. 6.10 & 6.11). Males outnumbered females in January, February, March, April, and December of 1997 and January, February, and April of 1998, while during the other months immature females (F1) were more abundant. These findings differ from the results obtained in other related studies where a ratio of 1:1 was found for male and female of any given species. (e.g. Laroche & Richardson, 1980, for *Engraulis mordax*). Similarly, Wright (1990) reported equal abundance of male and female *Stolephorus heterolobus* in South Java Sea, with the exception of 3 samples over 21 months of survey, when males were 2 to 3 times more abundant than females. However, other studies such as the one conducted by Milton *et al.* (1990a) on *Stolephorus heterolobus* in Solomon Islands and Maldives gave a consistently higher number of males, although females dominated in the larger specimens.

The abundance data presented in Figs. 6.10 and 6.11 also show that the sex ratio was reversed (either in favour of males or females) from stage 1 to stage 2 in 8 out of the 15 months of study. In February and April of 1997, M1 males outnumbered F1 females while F2 females outnumbered M2 males. In June, July, August, September of 1997 and January, February of 1998 the opposite was observed with more females at stage 1 while males were more numerous at stage 2. Parrish *et al.* (1986) also observed a change in the sex ratio of northern anchovy, *Engraulis mordax*, although always characterized by an increase of the female population. These authors suggested that

differences in growth rates and/or maturation of the gonads between both sexes could be responsible for these changes. This suggestion does not apply to the present study as the change in the sex ratio was not always in favour of the same gender

2.2.2. Spawning season and spawning ground

Mature females (F3) were found only in 5 months over the 15 months of study. Four of these months were successive months, from January to April 1997 (Fig. 6.10.c). Hence, it can be hypothesized that these months correspond to the main spawning season for *S. baganensis*. However, the presence of spent females in 12 of the 15 months of study (Fig. 6.10.d) also suggests that spawning occurred almost continuously. Several possibilities can be proposed to explain why there were few positive catches of F3 individuals. First of all, spawning anchovies tend to congregate and distance themselves from the non-spawning individuals (see also Leary *et al.*, 1975; Wright, 1992). Secondly, since the last two stages of ovum maturation, (i.e. the migratory-nucleus phase and subsequent hydration phase), can occur 6 to 8 hours and 4 to 6 hours, respectively, before spawning, as observed in some tropical fishes (Schaefer, 1996), it could be that the samplings, conducted in this study around 12 hours before spawning [based on Wright's (1992) estimated spawning time] were too early in the day to capture ripe individuals. On the other hand, mature males (M3) were found in 14 out of the 15 months of sampling (Fig. 6.11.c), suggesting that testis maturation occurs earlier in the day than ovary maturation. The difference in the rate of maturation of the males and females has also been noted in *Clupea harengus* in Finland where ripe males were observed months before the spawning season whereas the females were maturing much later. Subsequently, mature males make up a much higher percentage of the catches than to mature females. A third possibility for this low presence of mature females would be the presence of another spawning ground located outside of the study area,

which would be more important than the spawning ground at Sg. Selangor lower estuary.

2.2.3. Gonadosomatic index

The ovarian weight is affected by both the number and the size of eggs which respectively carry information regarding both fecundity and egg maturity (Jons & Miranda, 1997). Because both the number and size of eggs govern the ovarian weight and consequently the GSI, a straight forward relationship between GSI and spawning season cannot be easily established (Jons & Miranda, 1997). Some researchers associated the highest GSI with the beginning of the spawning season (Lowerre-Barbieri *et al.*, 1996), while others regarded the highest GSI as midway through the spawning season (Laroche & Richardson, 1980). GSI data from the present study showed two periods of relatively higher values of GSI, one around April 1997 and a second one around November 1997 (Figs. 6.14.a & 6.14.b), suggesting that major spawning occurred during these months.

In the present study, one striking feature is the relatively low monthly mean GSI in mature females that varied from 3.0 to 4.5 (Fig. 6.13.a), as compared to GSI values obtained for mature clupeoids of between 5.0 and 15.0 (e.g. Milton & Blaber, 1991; Rajasilta, 1992). Since the egg size of *S. baganensis* falls within the same size range as other engraulids mentioned in the literature (e.g. Blaber *et al.*, 1998), differences in fecundity appears to be the most likely explanation for the observed differences in GSI values amongst engraulids. This would imply that those species with larger ovaries relative to their body size or weight will have greater GSI values.

2.2.4. Relative condition factor

The relative condition factor is dependent on the gonad weight and the somatic weight. The latter varies with food availability, fish feeding behaviour, the energy allocated for gonadal maturation, and somatic growth (Le Cren, 1951). In this study the relative condition index is relatively high, generally above 2.0. These index values would indicate that fish are much heavier than expected by a factor neighbouring $\times 2$. Such high result values are surprising and lead to the questioning of measurement validity. Nevertheless, these results allow several observations based on the comparison of Kn values between months. Hence, the index fluctuated in a similar pattern as the abundance of mature adults (Figs. 6.10.c, 6.11.c, & 6.16). Therefore, these fluctuations are more the consequence of the increasing weight of the gonads (rather than the overall condition of the fish) since Kn values that were calculated according to gonadal maturation stage were relatively higher in mature fish (Figs. 6.17.a & b). However, a drop in Kn values would be expected even in mature individuals had they used energy reserves to sustain the development of the gonads, as for instance when food supply is short or the mature fish is not feeding. This was not observed in *S. baganensis*, suggesting that energy resources for reproduction were obtained through adequate food consumption.

The lower Kn values for indeterminate juveniles as compared to adults can easily be explained by the absence of gonads. Hence, monthly variation of Kn in indeterminate individuals (Fig. 6.16.c) cannot be attributed to a change in the gonad weight but to environmental conditions that were more favourable to somatic growth during certain months. In this study, it appears from the collected data that the period from February to March 1997 and the months of August and April 1998 were particularly 'bountiful' to these young juveniles (hence their high Kn values), whereas January, September, and

November of 1997, and February and March of 1998 appeared 'depauperate' since the indeterminate juveniles were characterized by poorer condition (Kn less than 1.0). Poorer production of food may not necessarily be the main cause of the juvenile's poor condition since plankton abundance was not particularly lacking (see, Fig. 4.2). These periods were however characterized by strong winds and heavy storms (see, Fig. 4.3.d) which could disperse plankton patches and consequently reduce food availability to the larvae.

2.2.5. Length-weight relationship

The relative growth coefficient or allometric constant of both male and female *S. baganensis* indicates adherence to the cubic law for isometric exponential growth. This implies maintenance of a constant length-weight ratio, or very little changes in the general body shape as the fish grows. Isometric exponential growth is also shown by other engraulids as for e.g. *Spratelloides delicatulus*, *S. gracilis*, and *Stolephorus heterolobus* from the Indo-Pacific region (see, Milton *et al.*, 1990).

3. *Thryssa kammalensis*

3.1. Stock density and biomass

Results on the abundance (no./ha) of *T. kammalensis* over the 16 months of survey (Fig. 6.18.a) show that this species is a temporary resident of the estuary because juveniles and adults were absent or very few for about half of the samplings conducted from January 1997 to April 1998. That *T. kammalensis* is a temporary resident is further supported by Zgozi (2000)'s findings; this species was recorded in only eight out of his 15 months of study in the whole Klang Strait. Similar results were observed for *T.*

hamiltonii in Moreton Bay (Australia), where adults disappeared entirely from the area in winter and spring (Blaber & Blaber, 1980), and for *T. vitrirostris* in South East Africa (Blaber, 1981). The results show that in Sg. Selangor lower estuary juveniles of *T. kammalensis* outnumbered adults, constituting more than 80% of the catch in more than 8 months of the study period, while adults constitute less than half of the catch except for three months (Fig. 6.19.a). Similarly, in the Ranong mangrove area (Thailand), adults of *T. setirostris* were found to be rare, whereas juveniles were relatively numerous (Agate *et al.*, 1991).

The presence of juveniles, together with all the different larval stages (see Chapter III, Section 2.1) and mature adults, suggest that *T. kammalensis* uses Sg. Selangor estuary both as a spawning and nursery ground. In contrast to *S. baganensis* species, *T. kammalensis* does not use the estuary as a permanent habitat. Blaber (1980) reported that *T. hamiltonii* were less abundant in an estuary than in a nearby-located bay in north-eastern Australia, thus suggesting that this species is not a true estuarine species, as is also the case for *T. kammalensis* in the present study. Blaber (1980) however did not report any correlation between adult abundance and distance from the shore or water depth.

The fluctuations in the ratio of adult to juvenile *T. kammalensis* are partly the consequence of episodic migrations of adults into the estuary in April - May of 1997 and February and April of 1998. On the other hand, the relatively low abundance of indeterminate juveniles from November 1997 to April 1998 is most probably due to the migration of young *T. kammalensis* from the estuary (nursery ground) into the offshore "maturation ground", as evident from the modes in January 1998 (Figs. 6.10.a & 6.11.a).

3.2. Reproductive biology

3.2.1. Spawning ground and spawning season

Like *S. baganensis*, *T. kammalensis* is a serial spawner since all ova stages were found in F2, F3, and F4 individuals (Fig. 6.6). Serial spawnings in females explain why the numbers of maturing (F2) and mature (F3) individuals were, on the whole, the same. This contrasts with *S. baganensis* where mature females were rare. As suggested in the literature for other engraulids (Wright, 1992), mature female *S. baganensis* could have segregated themselves from the rest of the cohort, or could not have been captured due to the short duration of this stage. However, these two suggestions cannot be applied to *T. kammalensis* since densities of F2 and F3 individuals were similar and frequency of captures of F3 *T. kammalensis* (10 months over 15 months) were higher than F3 *S. baganensis* (6 months over 15 months).

Few spent specimens were found over the study period (Figs. 6.21.d & 6.22.d) but the fact that the months of highest abundance for F3 (Fig. 6.21.c) and F4 (Fig. 6.21.d) were similar show that high spawning activities occurred in January, April, May, August, and November of 1997.

It has to be noted that the abundance of stage 3 females and to a lesser extent that of stage 4, as recorded from January to April of 1997 were not comparable with those from January to April of 1998, implying that yearly cycle of spawning may not be repeated. The results of this study suggest that spawnings occurred over a long period of about 10 months, with peaks every three months. After the spawning season, spent females seem to leave the estuary and do not come back (to spawn) until some time later. These conclusions are supported by Zgozi's (2000) findings which showed a relatively higher

number of *T. kammalensis* every three months for nine months (November 1996-July 1997), but beyond this period no fish were captured.

The male population was characterized by a relatively low density of mature and spent adult fishes (Figs. 6.22.c & 6.22.d). The much higher abundance of indeterminate juveniles (2.8 times) as compared to the entire immature population ($M1 + F1$) supports the contention that males only differentiate from the "indeterminates" when the latter migrate out of the estuary to the maturation ground. This contention is further substantiated by the relatively low abundance of M2 individuals over 6 months and by the absence of M2 and M3 individuals (Figs. 6.22.b & 6.22.c) over 6 and 13 months of the study period, respectively. However, the presence of so few mature males is difficult to explain considering the abundance of F3 females (Fig. 6.21.c) and the assumption that *T. kammalensis* uses the estuary as a spawning ground. However, four possibilities might be considered: (1) unlike ovaries, the testis of M3 male after extrusion of milt may not be significantly different from M2 male; (2) milt are released continuously and not altogether simultaneously; (3) the main spawning ground might not be in Sungai Selangor lower estuary, although the presence of (rare) spent males (Fig. 6.22.d) shows that *T. kammalensis* uses this estuary as a spawning ground; and (4) mature male individuals display strong sexual segregation and, in contrast to the females, do not stay in the estuary during the whole spawning season but make brief incursions into the spawning area to fertilise the eggs, and then depart. If the latter activity do occur at night, as usually is the case with clupeoids, this would explain why almost no M3 males were captured during the day. It has to be mentioned that sexual segregation has been observed in clupeids; for example in Sarawak (East Malaysia), Blaber *et al.* (1998) found only two males of *Ilisha filigera* whereas females at all gonad development stages were much more abundant. This phenomenon has, in some cases, been explained by

hermaphroditism. For example, the clupeiforme *Tenualosa toli* was found to be a protandrous hermaphrodite, changing from male to female at one year old (Blaber *et al.*, 1996). Hermaphroditism has also been suggested in the case of *Stolephorus* species but is not definite (Milton *et al.*, 1990b). In both studies, arguments were based on the abundance of either males or females above a defined fish length. In the present study, protandric hermaphroditism is not evident because there are no lack of class-lengths for males and females, but instead a relatively few number of mature individuals regardless of the size of the fish.

3.2.2. Gonadosomatic index

The uneven size between the right and left ovaries, as well as the inconsistent weight ratio of the two ovaries even in females of the same maturity, cannot be explained. Thus far there is no literature on this phenomenon for other fish species, although it has already been observed (Blaber, personal communication). The relatively high GSI from August to November of 1997 suggests that this period corresponded to the main spawning season (Fig. 6.25). However, the presence of spent individuals during the other months (i.e. January, April, May, August, and November of 1997) shows that spawnings did occur all year round (Fig. 6.21.d).

Male GSI were similar between M1 and M2 (Fig. 6.24.b), suggesting that captured M2 individuals were at the early phase of testis maturation. Hence, the absence of late M2 stage individuals together with the low number of mature males (M3), support the idea that juveniles depart from the estuary at either the "indeterminate" stage, or slightly later at the end of the juvenile stage.

The GSI values of *T. kammalensis* were higher than that of *S. baganensis* (Figs. 6.13.a & b and 6.24.a & b), thus suggesting a more ripe condition of mature female *T. kammalensis*, and/or bigger ovaries in the case of *T. kammalensis*. Monthly GSI for F3 *T. kammalensis* were quite variable (mean ranging between 3% to 7%) compared to F3 *S. baganensis* (mean ranging between 3% to 4.5%) indicating that ovary weight and/or density varied seasonally in *T. kammalensis*.

3.2.3. Relative condition value

The high Kn values recorded in May (Figs. 6.27.a, b, & c) matched the presence of mature males in that month, suggesting that gonad weight contributed to the increase of the condition factor. However, the relatively high values of GSI in August and September of 1997 (Fig. 6.24.a) did not correspond to any high Kn values observed in the same months, suggesting that the gonad weight is not the major variable responsible for the Kn values.

It is noted that for both males and females, the relative condition factors were higher for *T. kammalensis* (Figs. 6.28.a & b) than for *S. baganensis* (Figs. 6.17.a & b).

3.2.4. Length-weight relationship

The relative growth coefficient of both male and female *T. kammalensis* shows values slightly higher than 3.0 (i.e. 3.2 and 3.4 for female and male, respectively) implying little changes in the general body shape as the fish grows, and reflected by a faster gain in weight than growth in length.

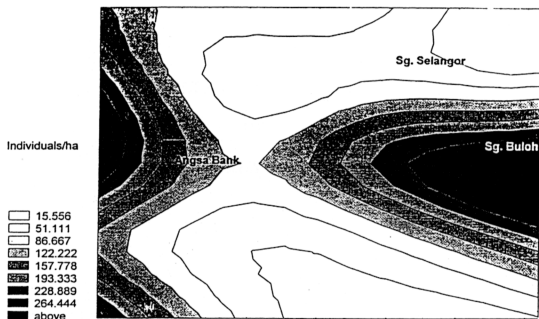


Fig. 6.29. Density contours (individuals/ha) of *S. baganensis* in the Klang Strait [From Zgozi, (2000)].